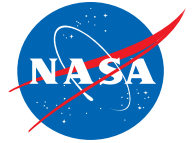


Non-Flow-Through Fuel Cell System Test Results and Demonstration on the SCARAB Rover

This presentation describes the results of the demonstration of a non-flow-through PEM fuel cell as part of a power system on the SCARAB rover at the NASA Glenn Research Center. A 16-cell non-flow-through fuel cell stack from Infinity Fuel Cell and Hydrogen, Inc. was incorporated into a power system designed to act as a range extender by providing power to the SCARAB rover's hotel loads. The power system, including the non-flow-through fuel cell technology, successfully demonstrated its goal as a range extender by powering hotel loads on the SCARAB rover, making this demonstration the first to use the non-flow-through fuel cell technology on a mobile platform.



Non-Flow-Through Fuel Cell System Test Results and Demonstration on the SCARAB Rover

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Power Sources Conference
Las Vegas, NV
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Presentation Overview

- AMPS project overview & demonstration goals
- SCARAB rover background
- NASA fuel cell development background
- Non-Flow-Through (NFT) Proton-Exchange-Membrane Fuel Cell (PEMFC) power system
- Demonstration & results

AMPS PROJECT OVERVIEW AND DEMONSTRATION GOALS

AES Modular Power Systems Project

- Project Objectives: AMPS will infuse and demonstrate modular batteries, fuel cells, and other power modules; and, develop modular power design concepts that will guide modular assembly development and ultimately be realized in exploration flight hardware



Demonstration Requirements and Objectives

Formal Objectives

- Integrate NFT fuel cell power system onto SCARAB rover
- Supply energy to SCARAB to extend mission duration
- Identify integration issues requiring further development to facilitate advancing the technology readiness level (TRL)

Formal Requirements

- Fuel cell power system must provide power to the SCARAB rover
- Cannot damage or modify the rover

SLOPE Test Facility

- Simulated Lunar Operations (SLOPE) Lab at NASA Glenn Research Center
- Used to study traction & power consumption of lunar vehicles operating in soil
- Simulated lunar regolith soil tank for flat surface operations & tilted soil tank for sloped surface operations

SCARAB ROVER

SCARAB Rover

- SCARAB owned and operated by Carnegie-Mellon University (CMU)
- Used in multiple field demonstrations and public relations activities
- Mobile Platform for experiments
 - ISRU
 - Lunar Tire Development
 - 12 Vdc NFT PEMFC



SCARAB Power Requirements

- 28 VDC Power Bus
- Hotel Loads: 175 W (communications, computer, cooling fans, etc.)
- Locomotion –
 - Stationary (elevation hold): 6 W (Total = 181 W)
 - Driving, level: 85 W (Total = 255 W)
 - Driving, turn: 200 W (Total = 375 W)
 - Elevating body: 225 W (Total = 400 W)
 - Peak Transient: 590 W (Total = 765 W)

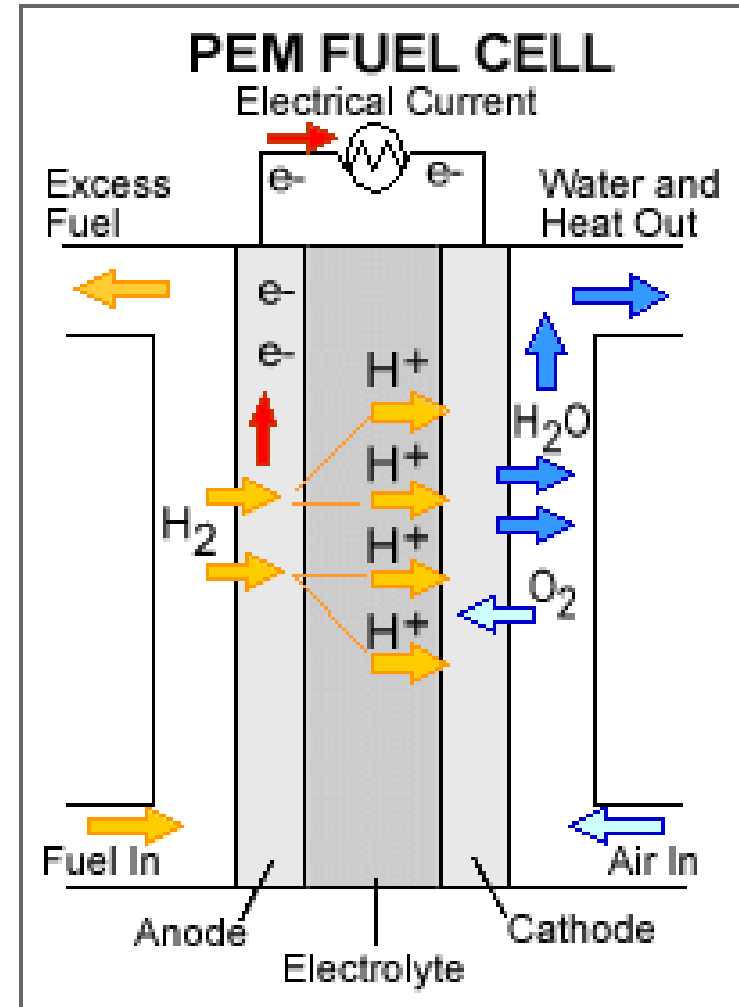
SCARAB Power

- SCARAB has on-board battery bank to provide power during normal operation
- Demonstration of NFT PEMFC power system on rover will act as a range extender by providing power to hotel loads while rover is stationary
- Rover not currently capable of power sharing, so power is provided by either SCARAB battery bank or fuel cell power system, but not both simultaneously

NASA PEMFC BACKGROUND

NASA PEMFC Background

- PEM fuel cells convert hydrogen and oxygen gases into water, waste heat, and electricity
- A fuel cell can provide power as long as reactants are available
- NASA NFT technology differs from traditional flow-through technology which operates in terrestrial environments and uses air as a reactant
- NASA missions operate in reduced and zero-gravity environments, and use pure oxygen as a reactant



NFT PEMFC Development

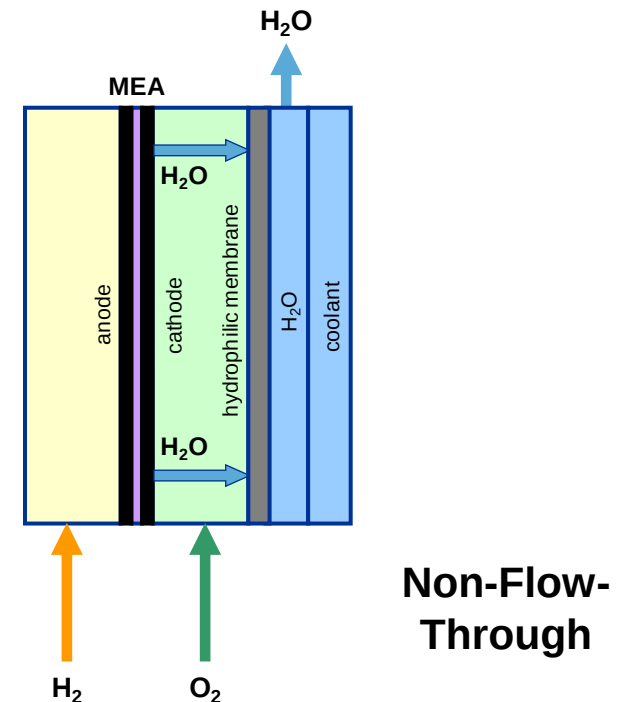
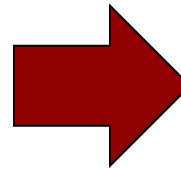
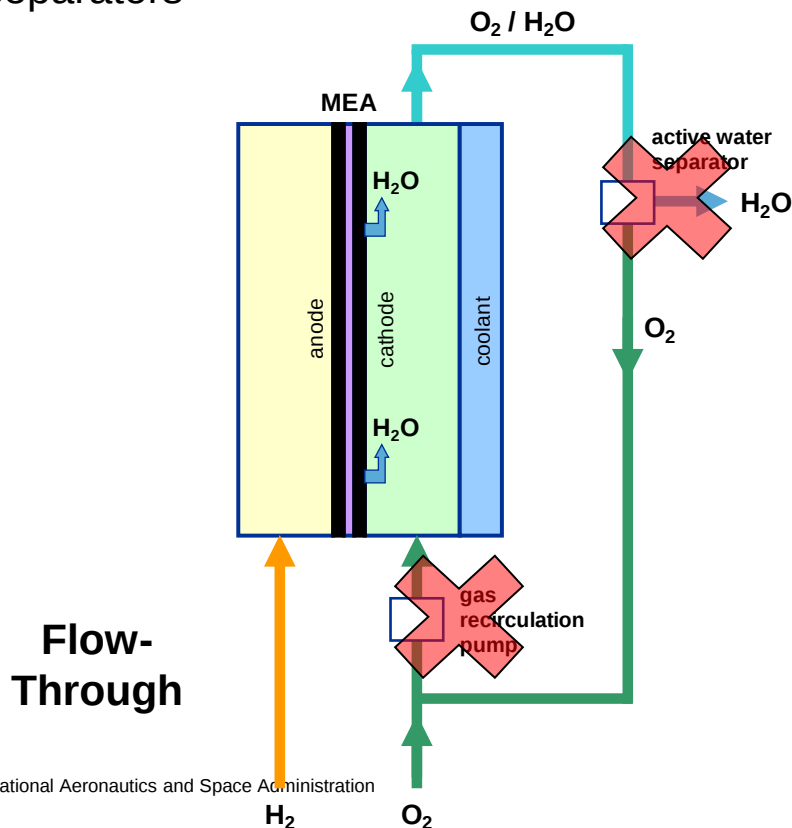
Develop “non-flow-through” proton exchange membrane fuel cell technology to improve system-level mass, volume, reliability, and parasitic power

Flow-Through components eliminated in Non-Flow-Through system include:

- Pumps or injectors/ejectors for recirculation
- Motorized or passive external water separators

Non-Flow-Through PEMFC technology characterized by dead-ended reactants and internal product water removal

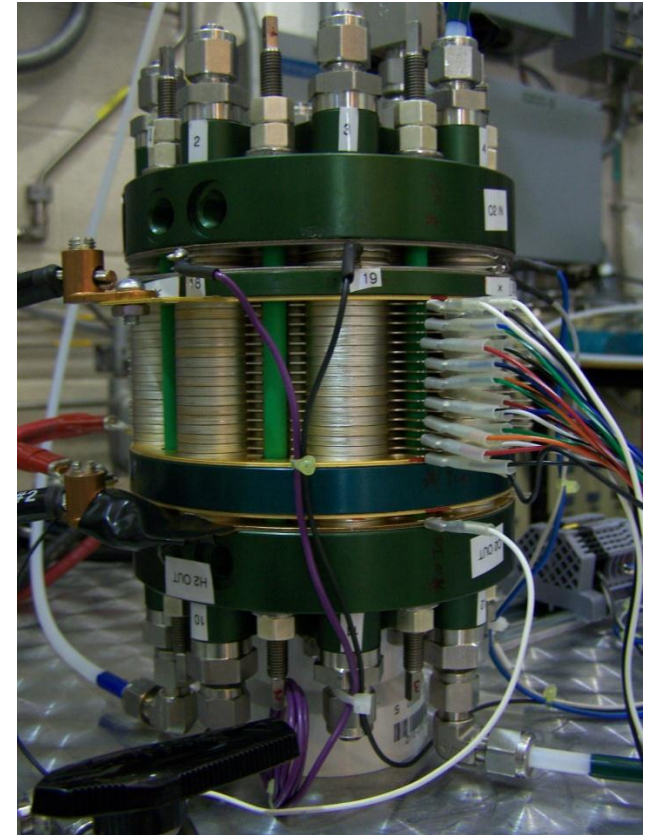
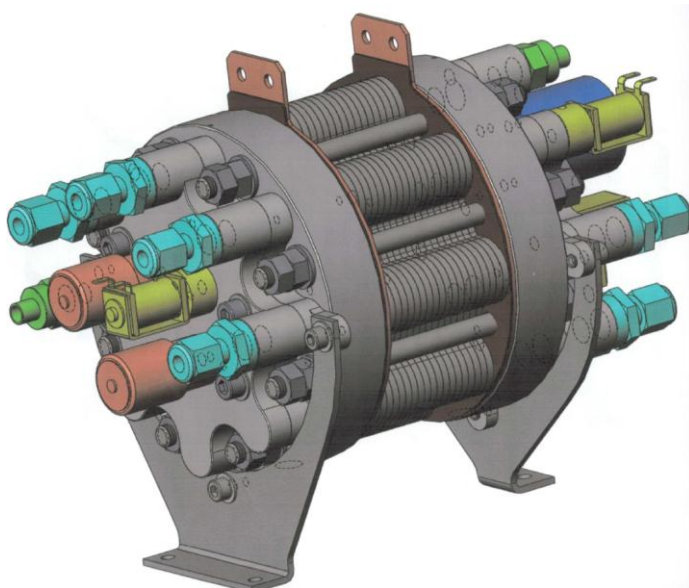
- Tank pressure drives reactant feed; no recirculation
- Water separation occurs through internal cell wicking



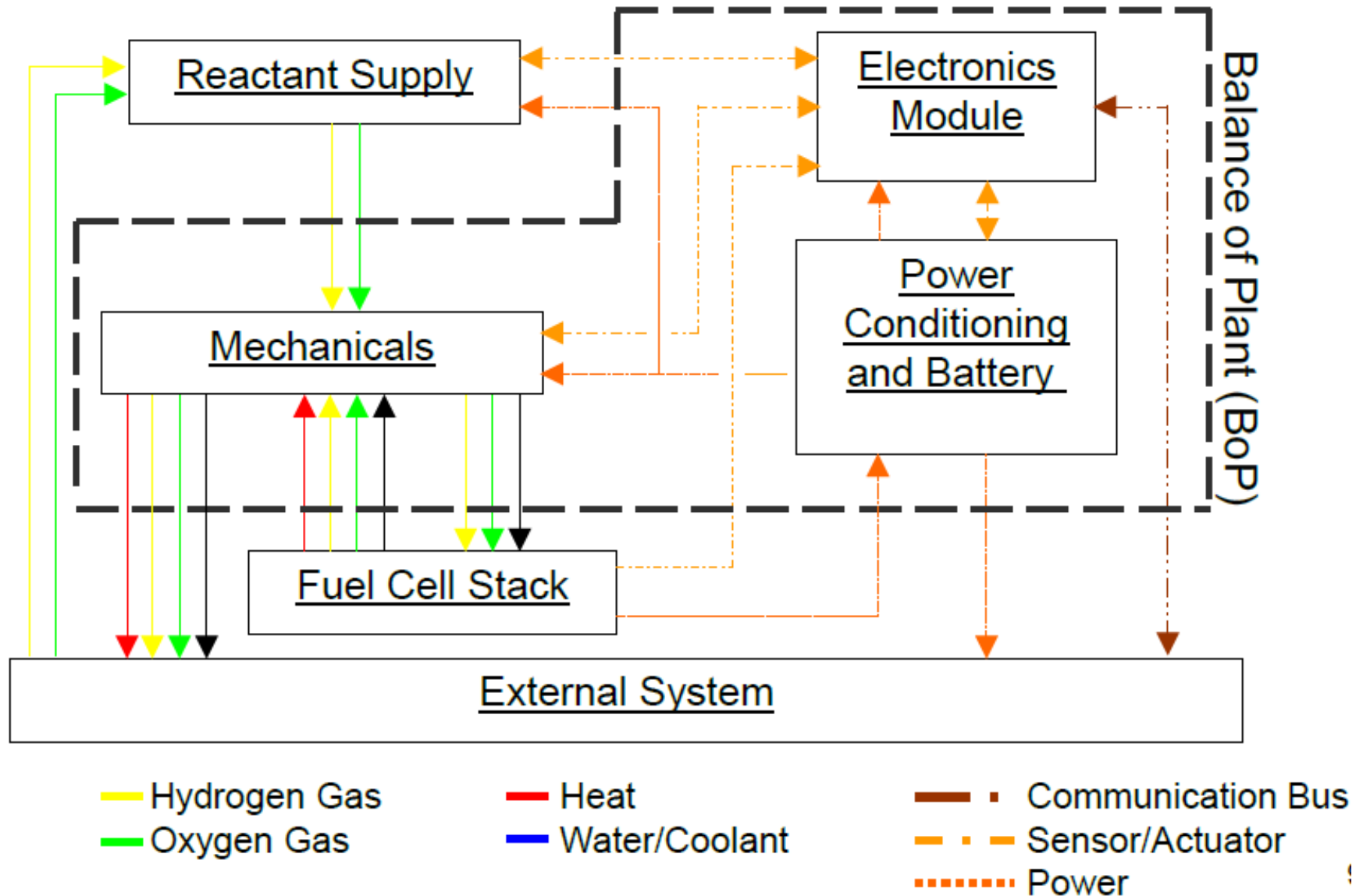
NFT PEMFC POWER SYSTEM

16-Cell NFT PEMFC Stack Overview

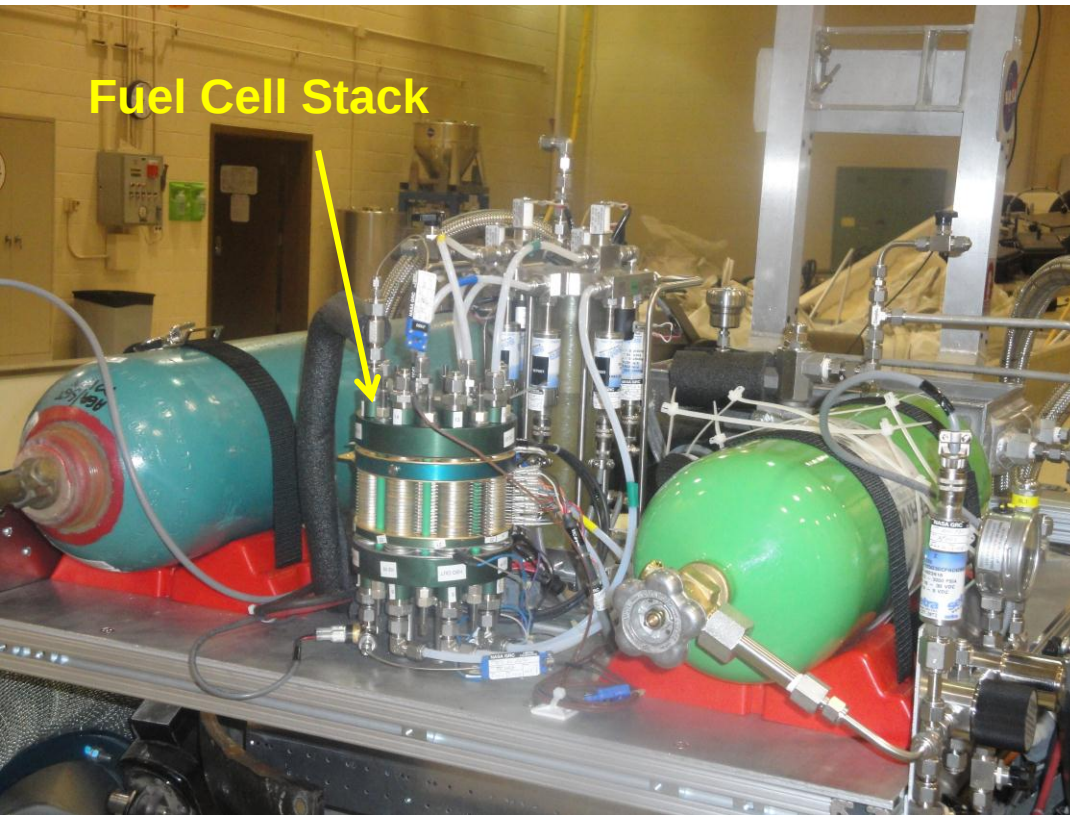
- Developed by Infinity Fuel Cell and Hydrogen, Inc.
- **TRL 4/5 technology**
- Active Area: 50 cm²
- Number of cells: 16
- Nominal Stack Voltage: 12Vdc
- Nominal Stack Power: 100 Watts



NFT PEMFC Power System



Demonstration Setup

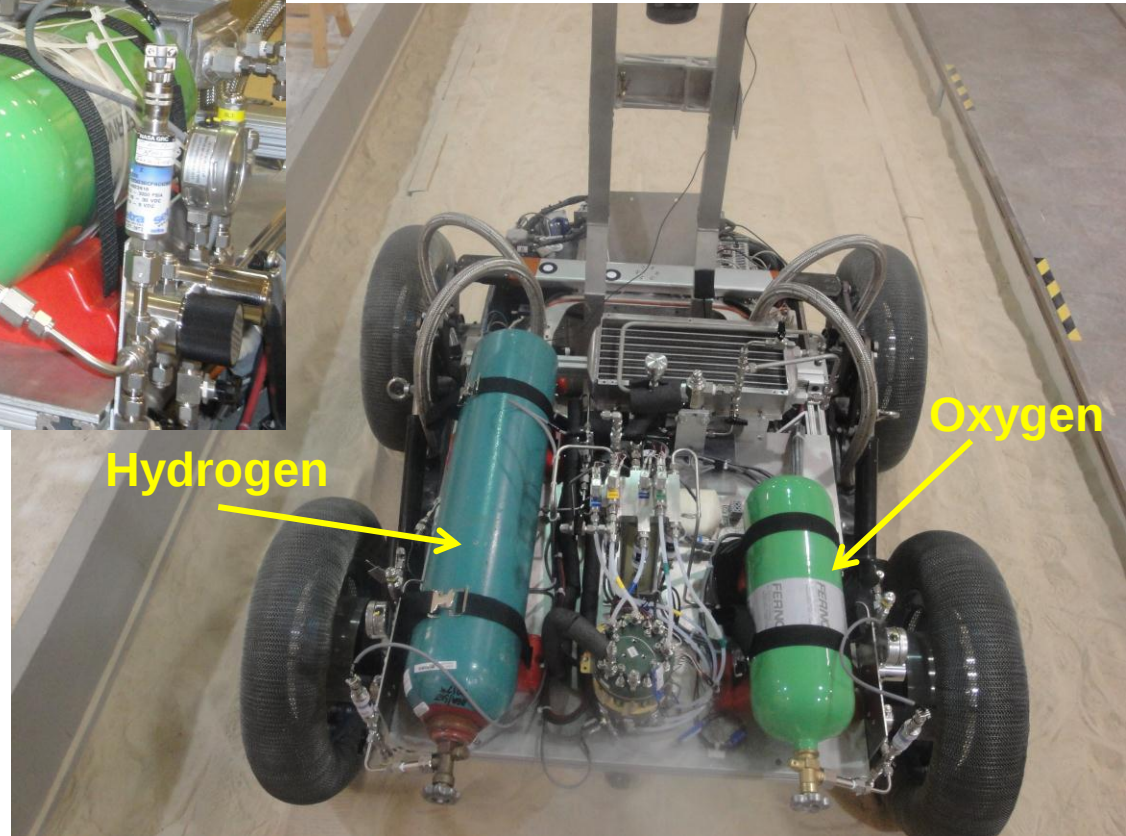


Fuel Cell Stack

- Power system mounted on Al plate secured to SCARAB

- Stack & reactants above plate
- Electronics drawer mounted below plate

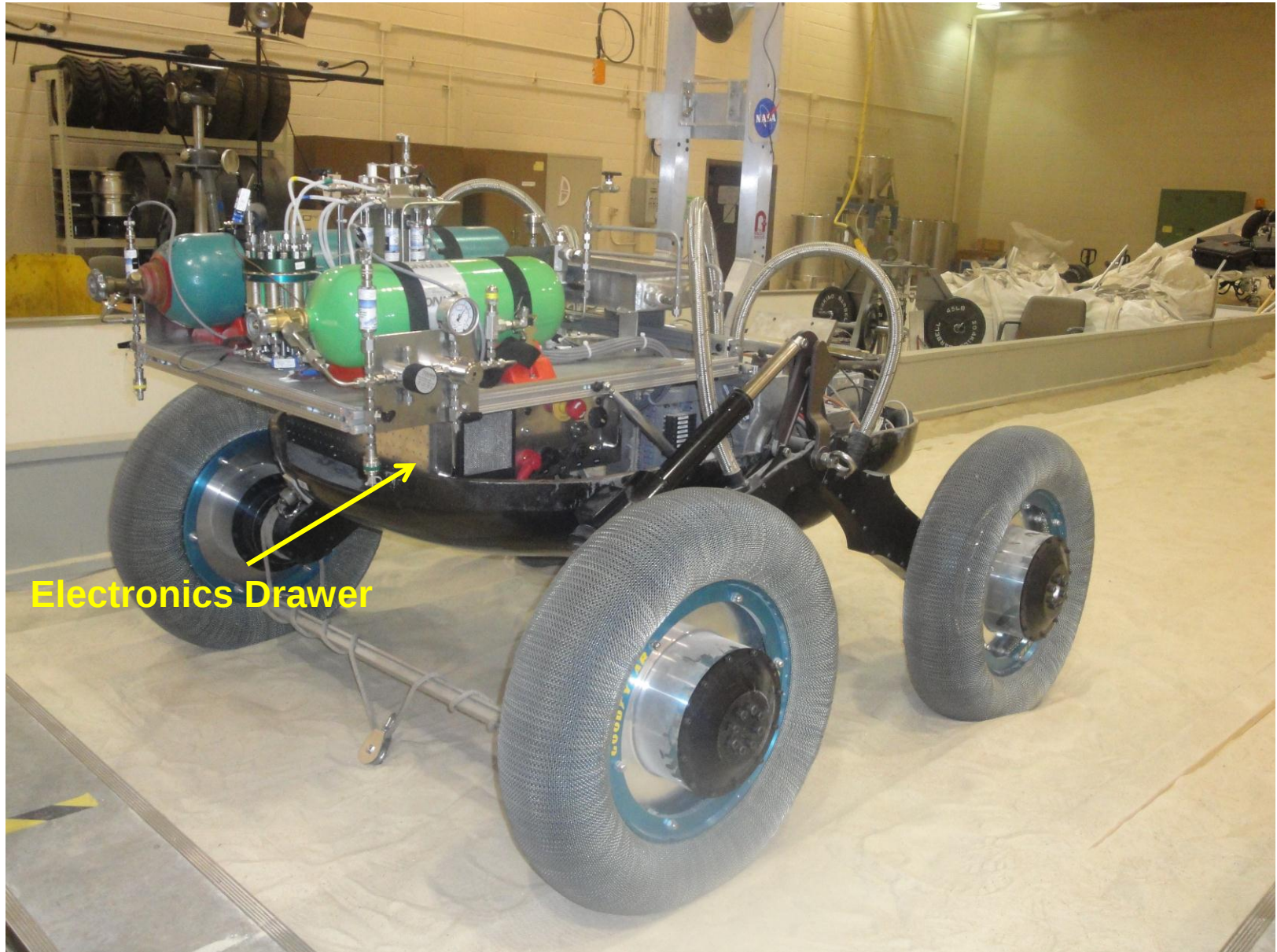
National Aeronautics and Space Administration



Hydrogen

Oxygen

NFT PEMFC Power System on SCARAB

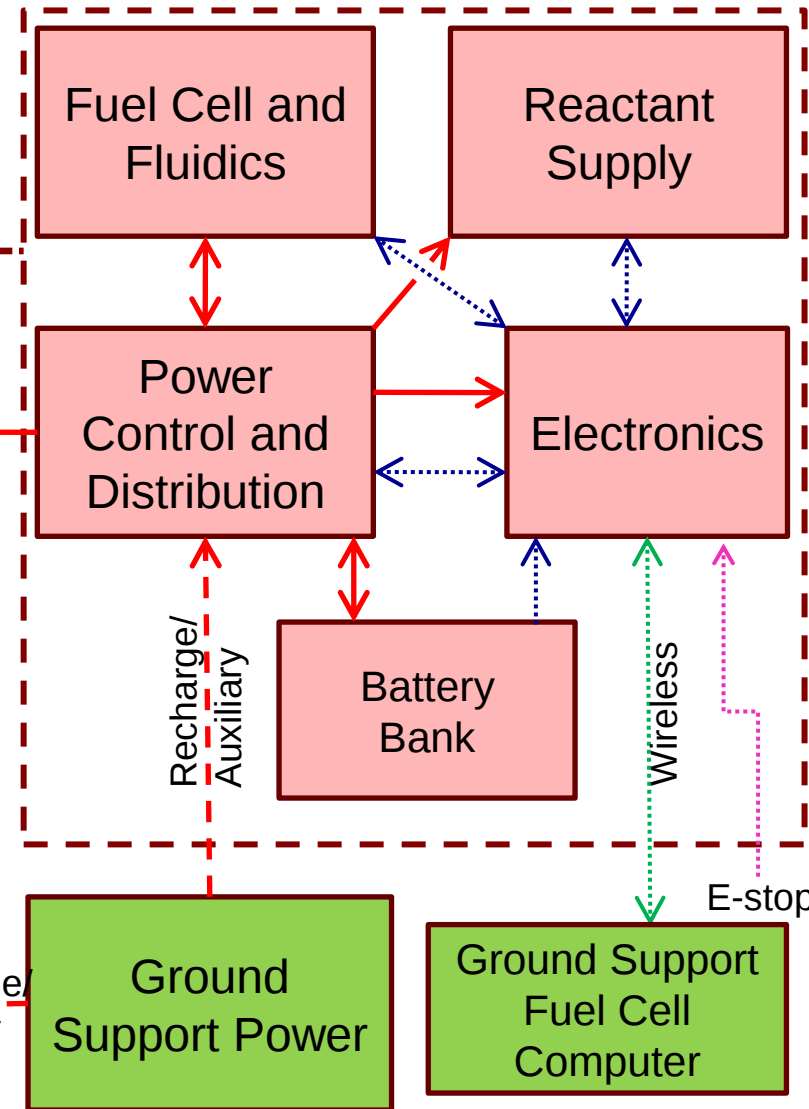


NFT PEMFC SYSTEM DEMONSTRATION & RESULTS

SCARAB Power Interface Concept



NFT PEMFC Power System



Or

SCARAB

SCARAB
Battery

Recharge/
Auxiliary

Ground
Support Power

Ground Support
Fuel Cell
Computer

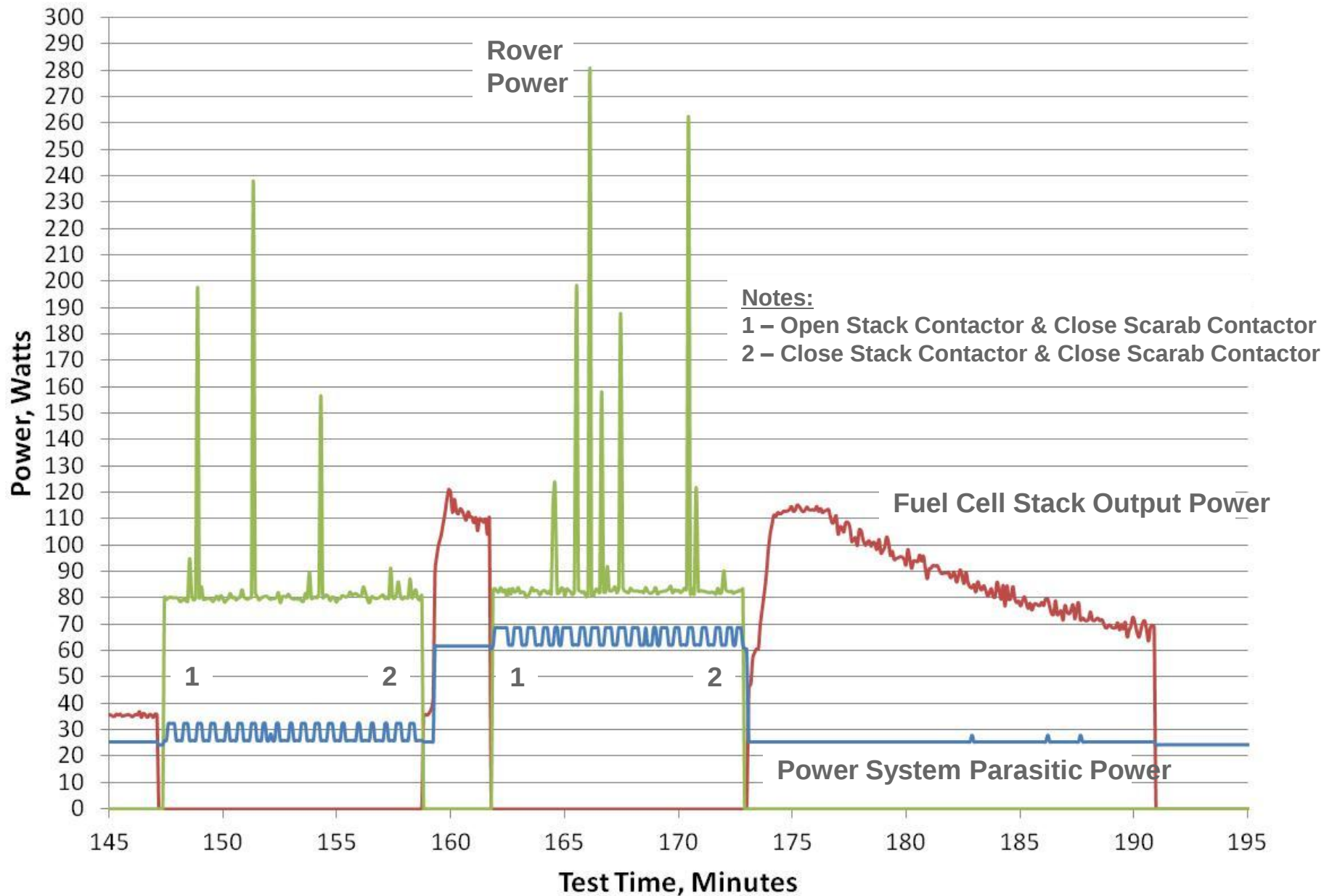
E-stop

Legend
 Power —
 Instrumentation/Control/Data
 Wireless Communication
 NFT PEMFC system E-stop

Demonstration

- Tests performed to verify system connectivity, stationary operation, and mobile operation
- Fuel cell power system successfully powered hotel loads during stationary operation
- 16-cell fuel cell stack is undersized for the SCARAB rover
 - An actual mission requiring fuel cells would match the fuel cell power capability with the mission requirements

Mobile Demonstration Power Profiles

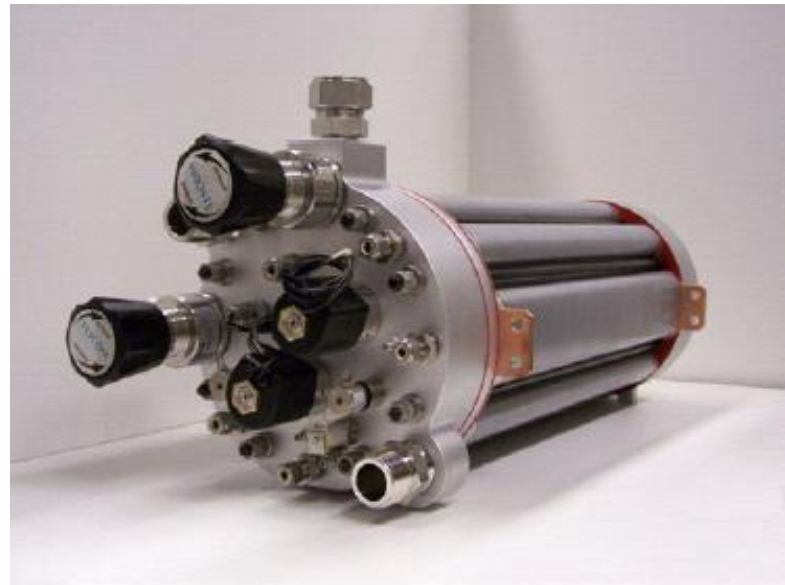
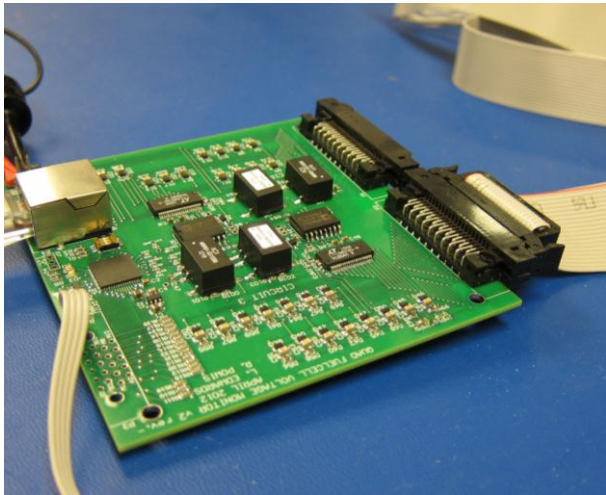


Summary

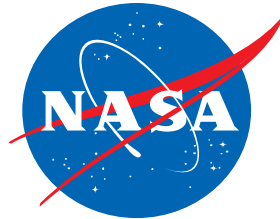
- Successfully integrated NFT fuel cell technology onto ground demonstration
 - Advances TRL of NFT PEMFC technology
- First demonstration of NFT PEMFC technology for a mobile application
- NASA continues to work to develop advanced NFT PEMFC systems to reduce mass, volume, and parasitic power

Future Activities for NFT PEMFC Power Systems

- Miniaturized electronics
- Advanced thermal & water management systems
- Advanced, custom interface plates with integrated balance-of-plant



Thank you. Questions?



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